BASELINE HUMAN HEALTH RISK ASSESSMENT FOR THE INHALATION PATHWAY YERINGTON MINE SITE

May 17, 2010

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ACRONYMS AND ABBREVIATIONS

ACCU	Automatic Cartridge Collection Unit		Site	Yerington Mine Site
AQM	Air Quality Monitoring		SOW	Scope of Work
Anaconda	Anaconda Company		TEEL	Temporary Emergency Exposure Levels
ARC	Atlantic Richfield Company			
ATSDR	Agency for Toxic Substances and Disease Registry		TENORM	Technologically Enhanced Naturally Occurring Radioactive Materials
CalEPA	California Environmental Protection Agency			
COPC	Chemical of Potential Concern			
CSM	Conceptual Site Model		TSP	Total Suspended Particulates
DSR	Data Summary Report			
DOE	Department of Energy		UCL	Upper Confidence Limits
EPA	Environmental Protection Agency		VLT	Vat Leach Tailings
ERPG	Emergency Response Planning Guidelines		WRCC	Western Regional Climate Center
FNB	Food and Nutrition Board			
HEAST	Health Effects Assessment Summary Tables		XRF	X-Ray Fluorescence Spectroscopy
HHRA	Human Health Risk Assessment		YPT	Yerington Paiute Tribe
HI	Hazard Index			
HQ	Hazard Quotient			
IRIS	Integrated Risk Information System		$\mu g/m3$	Micrograms per cubic meter of air
IUR	Inhalation Unit Risk			
MRL	Minimal Risk Levels		kg	kilogram
NAAQS	National Ambient Air Quality Standards		m3/min	Cubic Meters Per Minute
NAS	National Academy of Science		mg	milligrams
NDEP	Nevada Division of Environmental Protection		mg/kg/day	Milligrams per kilogram of body weight per day
OU	Operable Unit			
OSU	Oregon State University		mg/L	Milligrams per liter
OSWER	Office of Solid Waste and Emergency Response		mg/m3	Milligrams Per Cubic Meter
PPRTV	Provisional Peer-Reviewed Toxicity Values			
QAPP	Quality Assurance Project Plan		mm	Millimeters
REL	Reference Exposure Level		mph	Miles per Hour
REM	Roentgen Equivalent Man		pCi	Picocuries
RfC	Reference Concentration		PM_{10}	Particulate Matter Less Than 10 Microns in Size
RI/FS	Remedial Investigation and Feasibility Study			
RPD	Relative Percent Difference		risk/pCi	Risk Per Picocurie
RSL	Regional Screening Level			

EXECUTIVE SUMMARY

Atlantic Richfield Company (ARC) has developed this Baseline Human Health Risk Assessment for the Inhalation Pathway (HHRA) to determine if, under current conditions, the inhalation of dust (particulates)[1] at the boundary of the Yerington Mine Site (Site) poses a potential health concern above the risk associated with natural background for the area of the Site. In accordance with risk assessment guidance from the U.S. Environmental Protection Agency (EPA), "baseline" means a risk assessment that assesses the potential risk under current conditions, and assumes that these conditions are unchanging in the future (EPA, 1989). The concentrations of particulates, and associated chemicals and radiochemicals, in air measured at the Site boundary used in this HHRA are based on data summarized in the *Air Quality Monitoring Program Data Summary Report - Revision 2* dated September 3, 2009 (AQM DSR; Brown and Caldwell, 2009).

Conceptual Site Model
The Site is located about 0.5 miles west and northwest of the City of Yerington in Lyon County, Nevada within the Mason Valley. Large-scale exploration of the porphyry copper system began the early 1900s. In the period between 1953 and 1978, oxide ore, sulfide ore, low-grade dump leach oxide ore, low-grade sulfide ore, and waste rock/overburden were removed from a pit on the Site. Arimetco acquired the Site in 1988 and, from 1989 through 1997, constructed and operated five heap leach pad and an electro-winning plant until the company went bankrupt in 1997. Subsequently, mining and ore beneficiation operations at the Site have ceased (EPA, 2007). Current Site activities include the management of draindown fluids from the Arimetco facilities (heaps and ponds), operation and maintenance of the pumpback wells and associated evaporation pond, and Site investigations associated with the remedial investigation and feasibility study (RI/FS) process. Residual materials from the mining and ore processing remain on Site, and the following Operable Units (OUs) on the Site are potential sources of dust: Process Areas (OU-3), Evaporation Ponds and Sulfide Tailings (OU-4), Waste Rock Areas (OU-5), Oxide Tailings Areas (OU-6) and Arimetco Facilities (OU-8).

No residential areas are located on the Site. The closest off-site residential areas include residences on Luzier Lane, Locust Drive and the Sunset Hills residential area, a trailer park east of the Site and the community of Weed Heights. Other residential populations include the City of Yerington (about 0.5 miles to the east and southeast of the Site), the Yerington Paiute Tribe (YPT) Reservation (located about 2.5 miles north of the Site), and the YPT Colony (located adjacent to the City of Yerington).

SUMMARY OF AIR QUALITY MONITORING PROGRAM
Four types of data were collected during the three-year AQM program from January 2005 through March 2008:

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[1] The terms"dust" and "particulates" are used interchangeably in the HHRA. "Dust" is the term most often used by the general public while "particulates" is a more specific technical term.

- 24-hour average concentrations from high volume air samples for particulates, inorganic chemicals and radiochemicals were collected during 187 monitoring events resulting in 40,516 analytical results.

- Hourly average concentration samples for PM_{10} (particulate matter less than 10 micrometers in diameter) for a total of 28,680 data points.

- Periodic samples for metals collected when PM_{10} concentrations exceeded trigger levels resulting in five samples representative of "dust events".

- Meteorological data collected during the AQM program consisted of wind speed and direction, precipitation, temperature, relative humidity, solar radiation, and barometric pressure.

The evaluation of these data included determination of wind speed and direction, correlation of 24-hour average and hourly average PM_{10} concentrations, comparison of 24-hour average PM_{10} and total suspended particulates (TSP) results, dust event results, and comparison of upwind and downwind concentrations for the analytical data. Key findings that are most relevant to the HHRA are as follows:

- Upwind and downwind PM_{10} concentrations at the Site are similar to regional background concentrations.

- The concentrations of PM_{10} aluminum and copper increase as wind passes across the Site based on 24-hour average concentrations.

- The concentrations of some metals and radiochemicals may increase as wind passes over the Site during extreme high wind events although the data are limited to a comparison of two samples.

Results of Chronic (Long-Term) and Acute (Short-Term) Human Health Risk Assessments
The results of the chronic and acute HHRAs: 1) do not indicate a potential for increased health effects associated with dust from the Site; and 2) show that inhalation of $PM_{10,}$ regardless of the source (background or site-related), is unlikely to result in adverse health conditions. In the chronic HHRA, the cumulative cancer risks and noncancer hazard values (including background) are within the risk management levels set by EPA. Lead and PM_{10} concentrations meet National Ambient Air Quality Standards.

The risk calculations presented in this HHRA, designed to assure that exposure is not underestimated, are based on the assumption that a hypothetical resident lives outdoors at the air monitoring stations located on the Site boundary for 30 years and breathes the air 24 hours a day for 350 days a year. The EPA risk assessment methodology used in this chronic HHRA is a tool that regulators use to make decisions determining whether site-related releases warrant action to reduce exposure. The methodology does not predict actual cases of cancer or any health effect.

In evaluating the contribution from the Site to downwind concentrations, statistically-higher downwind concentrations were found for three parameters (PM$_{10}$, aluminum and copper). However, the health risks are well below the EPA target level and any increase in concentrations as the air passes over the Site do not cause the concentrations to exceed EPA guidelines. The concentrations of PM$_{10}$ are also below national guidelines.

In the acute HHRA, none of the estimates of short-term exposure (including an extreme "worst-case" estimate) exceed acute guidelines. The "worst-case" estimate assumes that all the PM$_{10}$ (represented by the 99.7 upper confidence limit of the 24-hour average concentration) occurred within 15 minutes. Comparison of two 24-hour average samples collected during the day of the highest wind and dust conditions recorded during the three-year air quality program (June 5, 2007) indicates that concentrations of some parameters may increase as wind passes over the Site under these conditions. However, the short-term concentrations indicate that any such increases would be below health-based exposure guidelines.

SECTION 1.0

INTRODUCTION

Atlantic Richfield Company (ARC) has developed this Baseline Human Health Risk Assessment for the Inhalation Pathway (HHRA) to determine if the inhalation of dust (particulates) [2] at the boundary of the Yerington Mine Site (Site) poses a potential health concern under current conditions. The Site is located near the City of Yerington in Lyon County, Nevada. In accordance with risk assessment guidance from the U.S. Environmental Protection Agency (EPA), "baseline" means a risk assessment that assesses the potential risk under current conditions and assumes that these conditions are unchanging in the future (EPA, 1989). The concentrations of particulate matter, and associated chemicals and radiochemicals, in air measured at the Site boundary used in this HHRA are based on data summarized in the *Air Quality Monitoring Program Data Summary Report - Revision 2* dated September 3, 2009 (AQM DSR; Brown and Caldwell, 2009).

This HHRA has been developed as part of the Scope of Work (SOW) attached to the Administrative Order (Order) for Remedial Investigation and Feasibility Study (RI/FS) for the Anaconda/Yerington Mine Site issued by the EPA - Region 9 to ARC on January 12, 2007 (EPA, 2007). Although not specified in the SOW, ARC has voluntarily prepared this HHRA to respond to community concerns regarding potential inhalation exposures. The Site location is shown in Figure 1-1. The operable units (OUs) identified in the Order and attached SOW are depicted in Figure 1-2.

This HHRA presents the methodology that was used to evaluate lifetime or chronic health effects and short-term or acute health effects (EPA, 1989; 2006; 2009 and CalEPA 2003). This HHRA includes the following sections:

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[2] The terms "dust" and "particulates" are used interchangeably in the HHRA. "Dust" is the term most often used by the general public while "particulates" is a more specific technical term.

- Section 2.0. Conceptual Site Model (CSM) describes the Site, topographic features, climate, land use, the nearest populations and an overview of local meteorological conditions.

- Section 3.0. Summary of Air Quality Monitoring Program describes the collection of data from January 2005 through March 2008, which are the basis for the HHRA calculations.

- Section 4.0. Chronic (Long-Term) HHRA evaluates the possibility that average concentrations of PM_{10}, associated chemicals and radiochemicals could have an effect on health over a lifetime.

- Section 5.0. Acute (Short-Term) HHRA evaluates the possibility that peak PM_{10} concentrations and associated chemicals and radiochemicals could have a short term impact on health. TSP was also evaluated.

- Section 6.0 Uncertainty Analysis discusses the areas of uncertainty and the level of confidence that can be placed in the results of the HHRA.

- Section 7.0 Summary and Conclusions

SECTION 2.0

CONCEPTUAL SITE MODEL

The information presented in this section, based on the *Conceptual Site Model - Revision 3* dated January 30, 2009 (Brown and Caldwell et. al., 2009), summarizes the current understanding of the physical features of the Site, known and potential sources of mine-related impacts, known and potential chemical migration pathways, and human populations that may contact mine-related releases.

2.1   Site Location

The Site is located about 0.5 miles west and northwest of the City of Yerington in Mason Valley, within the Walker River watershed (Figure 1-1). Mason Valley includes over 39,000 acres of irrigated (Lopes and Smith, 2007). Agriculture has been the principal economic activity in Mason Valley, including hay and grain farming, with some beef and dairy cattle ranching and local onion farming in the area north of the Site. Irrigation water is provided from surface water diversions from the Walker River and from groundwater. The Walker River flows northerly and northeasterly between the Site and the town of Yerington (the river is within a quarter-mile of the southern portion of the site). Approximately half of the Site is owned by Arimetco subject to the supervision of the Federal Bankruptcy court in Tucson, Arizona and the other half is owned by the U.S. Bureau of Land Management. ARC does not own any of the land associated with the Site.

2.2   Physical Setting

The physical setting of the Site is within the Basin and Range physiographic province, which is part of the Great Basin sagebrush-steppe ecosystem. Mason Valley occupies a structural graben (i.e., down-dropped faulted basin) immediately east of the Singatse Range, an uplifted mountain block. Vegetative communities in the area vary from relatively dense associations along the Walker River immediately east of the Site to sparse brush found on the alluvial fans derived from Singatse Range, immediately west of the Site. Mining and ore processing activities at the Site

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have resulted in modifications to the natural, pre-mining topography, including a large open pit (occupied by a pit lake), waste rock and leached ore piles, and evaporation and tailings ponds.

Climate

The Site is located in a high desert environment characterized by an arid climate. Monthly average temperatures range from the low 30s °F in December to the mid 70s °F in July. Annual average rainfall for the town of Yerington is only 5.3 inches per year, with lowest rainfall occurring between July and September (WRCC, 2007a). Sporadic thunderstorms may occur throughout the year and past storms have resulted in rain events of up to approximately 2 inches in a single day (WRCC, 2007b).

Air quality and meteorological data collected since 2002 indicate that wind direction is variable at the Site with no quadrant representing over 50 percent of the total measurements. When wind speeds are above 15 miles per hour (mph), however, there is a predominant wind direction to the northeast (Brown and Caldwell, 2009). Additional meteorological information is provided in the quarterly air quality monitoring reports for the Site.

Geologic Setting

The structurally uplifted mountain ranges in the area of the Site, typical of basin-and-range topography, are primarily composed of granitic and volcanic rocks, with minor amounts of metamorphic rocks. In addition to these bedrock types, semi-consolidated to unconsolidated alluvial fan deposits occur along the margins of the mountain block. The Singatse Range, located immediately west of the Site, has been subject to extensive metals mineralization as a result of natural processes. This is evidenced by the large copper porphyry ore deposit at the Site, other surface mines and prospects, and mineralized bedrock in the subsurface underlying the Site.

Unconsolidated alluvial deposits derived by erosion of the uplifted mountain block of the Singatse Range and alluvial materials deposited by the Walker River fill the structural basin occupied by Mason Valley in the vicinity of the Site. The thickness of alluvium in the area of

the Site generally increases from south to north and from west to east, consistent with the development of alluvial fan, transitional, and flood-plain/lacustrine depositional environments away from the Singatse Range front. At the location of the Yerington Pit, the thickness of unconsolidated alluvial sediments is typically a few tens of feet, but may be up to 168 feet thick. In the vicinity of the tailings areas at the northern margin of the Site, the thickness of the alluvium exceeds 600 feet. The alluvial deposits consist of clastic sediments ranging in size from clay to cobbles. Relatively coarse-grained alluvial fan (fine sand) and fluvial (coarse sand to cobble) deposits comprise the major aquifer materials and serve as the principal sources of water for domestic wells and high-capacity irrigation wells in the area.

2.3   Past Mining Operations

Copper in the Yerington district was initially discovered in the 1860s, with large-scale exploration of the porphyry copper system occurring in the early 1900s when the area was organized into a mining district by Empire-Nevada Copper Mining and Smelting Co. Mining, milling, and leaching operations for oxide and sulfide copper ores from an open-pit in the southern portion of the mine site were conducted between 1953 and 1978 by ARC's predecessor, The Anaconda Company (Anaconda). Once ARC divested itself of the Site, subsequent operators (e.g., Arimetco) used some of the buildings for operational support; the Anaconda-constructed processing components remained inactive during this period.

Anaconda conducted mining only in the Yerington Pit from the period between 1953 and 1978. Categories of material removed from the pit included: 1) oxide ore; 2) sulfide ore; 3) low-grade dump leach oxide ore; 4) low-grade sulfide ore; and 5) waste rock/overburden. The open pit was mined in 25-foot benches with a 45 degree pit wall slope. Final dimensions of the mined pit are approximately 6,200 feet long, 2,500 feet wide, and 800 feet deep. The steps in the mining process were as follows:

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- ▪ Crushing and Grinding - Ore was crushed prior to leaching or processing in the plant.

- ▪ Leaching (Oxide Ore) - Sulfuric acid leach solution was used to leach copper from the ore. Spent ore, known as oxide tailings or vat leach tailings (VLT) was washed twice to remove the acid and then hauled to the oxide tailings or VLT pile (collectively comprising OU-6).

- ▪ Cementation/Precipitation (Oxide Ore) - Copper was recovered from the leach solution by precipitating (i.e., "cementing") the copper using scrap iron. The copper cement was hauled offsite for final smelting to a pure copper product.

- ▪ Concentrator (Sulfide Ore) - The finished concentrate was hauled offsite. Residual solutions, containing elevated concentrations of iron and sulfate as well as uranium and other radiochemicals, were conveyed to evaporation ponds (Seitz et al., 1982). Excess pulp present after the floatation separation was disposed in the sulfide tailings.

Sulfuric Acid Production - Sulfuric acid was produced at the Site at the Acid Plant from raw sulfur ore shipped from the Leviathan Mine located in Alpine County, California. The ore was crushed to minus 10 mesh (<2 mm) and then roasted to drive SO_2 gas from the ore, which would then be converted to sulfuric acid. The burned ore or "calcines" were conveyed via the Calcine Ditch to evaporation ponds for disposal.

Other sources of these materials include the Arimetco operation, which is adjacent to the Site. In 1989, Arimetco, Inc. initiated leaching operations that would eventually encompass five lined leach pads located around the site including the rehandling and leaching of previously deposited waste rock north of the pit. Arimetco also constructed and operated an electro-winning plant with associated solution ponds located south of the former mill area. Some Arimetco leach pads and solution ponds were constructed on the pre-existing Anaconda processing and tailings areas, including the oxide tailings areas, the W-3 dump leach, and the sulfuric acid plant. Arimetco ceased mining new ore and leaching operations in November 1998 and continued to recover copper from the heaps until November 1999.

2.4   Current Conditions

Mining and ore beneficiation operations at the Site have ceased and Site mining and processing areas are no longer active (EPA, 2007). Current Site activities include: 1) the management of draindown fluids from the Arimetco facilities (heaps and ponds), which started in 1999; and 2)

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operation and maintenance of the pumpback wells and associated evaporation pond, which started in 1985 under an Administrative Order issued to Anaconda by NDEP. In addition, Site investigations associated with the RI/FS process and removal actions have occurred during the period 2000 through the present. Public access is discouraged through the use of perimeter fencing and warning signs, and Site security is maintained by ARC.

2.5   Potential Sources of Dust

Potential sources of particulates on the Site include undisturbed and disturbed soils, tailings, overburden (soil above the copper ore body), waste rock materials and evaporative residues. Five of the OUs, shown in Figure 1-2 and listed below, are potential sources of particulates from the Site (the remaining OUs are not considered sources of particulates):

- Process Areas (OU-3)
- Evaporation Ponds and Sulfide Tailings (OU-4)
- Waste Rock Areas (OU-5)
- Oxide Tailings Areas (OU-6)
- Arimetco Facilities (OU-8)

The chemicals associated with the particulates include metals, other inorganic chemicals such as sulfate, and radiochemicals. The mineralogical characteristics of the ore and waste rock mined from the Yerington open pit, in conjunction with the ore processing activities, have resulted in the occurrence of technologically enhanced naturally occurring radioactive materials (TENORM), resulting in the need to analyze for radiochemicals as part of the air quality monitoring (AQM) program.

In addition to dust from the Site, there are other anthropogenic (man-made) sources of these dust in Mason Valley including other mine sites (e.g., the Bluestone Mine, located southwest of the

Site), agricultural fields and dirt roads as well as natural sources from undisturbed soil. These sources, which occur all around the Site and other sources located outside of Mason Valley, have been observed to contribute to particulates in the air around the Site.

2.6   Adjacent Residential Areas

No residential areas are located on the Site.   The closest off-site residential areas include residences on Luzier Lane which are less than one hundred yards away from the northern property boundary of the Site, residences along Locust Drive and north on Sunset Hills Drive (Sunset Hills residential area), a trailer park east of the Site and the community of Weed Heights (Figure 1-1). Other residential populations include the City of Yerington (about 0.5 miles to the east and southeast of the Site), the Yerington Paiute Tribe (YPT) Reservation (located about 2.5 miles north of the Site) and the YPT Colony (located adjacent to the City of Yerington).

Approximately 2,880 people (1,200 households) and 5,730 people (2,700 households) live within one and three miles, respectively, of the Site boundary (ATSDR, 2006; U.S. Census Bureau 2000). Most of these people live in the City of Yerington. The population density is lower to the north and west of the Site, although new residential development is occurring to the north (ATSDR 2006). Members of the YPT include approximately 175 members living east of the Site in the Colony and approximately 400 members living on the reservation north of the Site (ATSDR, 2006). Commercial and industrial businesses operate in Weed Heights, the City of Yerington, and along Highway 95A between the Site and the City of Yerington.

SECTION 3.0

SUMMARY OF AIR QUALITY MONITORING PROGRAM

This section of the HHRA describes the data collected by ARC at the Site from January 2005 through March 2008 as part of the Air Quality Monitoring (AQM) program as presented in the AQM Data Summary Report Revision 2 (DSR) (Brown and Caldwell, 2009). The following is a brief description of the data collected during the AQM project and the findings of the evaluation of these data.

3.1   Overview of Air Quality Monitoring Program

This section presents an overview of the AQM program and describes the four types of data collected during the AQM program:

- 24-hour average concentrations from high volume air samples for particulates, inorganic chemicals and radiochemicals;
- Hourly average concentration samples for particulates;
- Periodic samples for metals collected when particulate concentrations exceeded trigger levels(called "dust events" in this report; and
- Meteorological data

The AQM program was initiated in the fourth quarter of 2004 with preparation of a work plan and construction of six air monitoring locations (AM-1 to AM-6) for collecting 24-hour high volume air samples (Figure 1-1). AM-1 had an additional co-located PM_{10} high volume air sampler for the collection of duplicate (i.e., co-located) samples. A Site meteorological station with instrumentation for measuring wind speed/direction, temperature, relative humidity, barometric pressure, solar radiation, and precipitation was already continuously operating at Pumpback Well PW-06 (near AM-6). The types of samples collected at each location varied as well as the locations sampled during the three-year air quality program. A schedule of the various types of sampling is provided in Figure 3-1.

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EPA provided oversight throughout the AQM program including: reviewing/approving work plans and program changes; conducting periodic program and instrumentation audits; and reviewing/approving of quarterly monitoring reports and the Data Summary Report.

All analytical data were verified and validated in accordance with the Quality Assurance Project Plan (QAPP - Revision 5; Environmental Standards, Inc. and Brown and Caldwell, 2009). The 24-hour average concentration data for particulates, inorganic chemicals and radiochemicals had robust quality control which included the evaluation of field duplicates (i.e., co-located samples), field blanks, filter blanks (i.e., trip blanks), method blanks, blank spikes, and blank spike duplicates. The periodic samples for metals in "dust events" had minimal quality control which included the evaluation of field and filter blanks.

3.1.1   24-Hour Average Concentration (High Volume) Samples

Two types of high volume air samplers were installed at each monitoring location for collecting data on 24-hour average concentrations of two categories of airborne particulates:

- Total suspended particulates (TSP); and
- PM_{10}, a subset of TSP (which is considered the respirable fraction).

High volume sampling of particulates began on January 28, 2005 and continued nearly every sixth day in accordance with the National Ambient Air Quality Standards ("NAAQS") monitoring schedule. A total of 187 monitoring events were conducted through March 2008 and 40,516 24-hour average concentration analytical results were generated during the AQM program. These high volume air samples were collected at high flow rates (e.g., 1.13 cubic meters per minute [m^3/min]) over a 24-hour period (midnight to midnight), which resulted in a large volume of ambient air (e.g., 1,630 cubic meters). The 24-hour average concentration is the mass of material on the filter divided by the volume of air that passed through the filter. The filters from these air samples were analyzed for TSP, PM_{10}, 21 metals and ten radiochemicals.

On July 4, 2006, the AQM program was revised to terminate all sampling at locations AM2, AM-4, and AM-5 because analytical results at these locations correlated well with the remaining

locations AM-1, AM-3, and AM-6. In addition, TSP high volume air sampling was terminated at locations AM-1 through AM-5 because TSP analytical results correlated well with PM_{10} results. PM_{10} high volume air sampling continued at AM-1, AM-3, and AM-6 and TSP high volume air sampling continued at AM-6. The analyte list was modified by adding sulfate, reducing metals from 21 to eight, and reducing radiochemicals from ten to five. Analytes were removed from the list for the following reasons: infrequent detections, detections significantly lower than regulatory comparison risk levels, or because they are required nutrients (e.g., calcium).

On December 19, 2006, sampling activities were suspended and all TSP high volume air samplers were decommissioned from all locations, including AM-6. No additional TSP data were collected during the AQM program. The PM_{10} high volume air samplers at locations AM-1, AM-3, and AM-6 resumed operation on February 5, 2007 following construction activities and installation of new continuous PM_{10} air monitoring equipment. PM_{10} high volume sampling continued until September 27, 2007 when the remaining PM_{10} high volume air samplers were shut down because high volume PM_{10} results correlated well with continuous PM_{10} results and because over two years of inorganic and radiochemical data had been acquired.

3.1.2 Hourly Average Concentrations and Dust Event Samples

Starting in February 2007, hourly average PM_{10} samples were collected via continuous particulate monitors installed at three locations (AM-1, AM-3, and AM-6) to characterize short term "dust events". Continuous hourly average PM_{10} sampling continued through March 2008 for a total of 28,680 data points.

As part of the revisions to the AQM program in 2007, a "dust event" was numerically defined as an hourly PM_{10} concentration that exceeded 300 $\mu g/m^3$ measured at AM-6. When PM_{10} concentrations exceeded this trigger level at AM-6, sample collection on a filter cassette was automatically triggered. The automatic system continued to sample as long as the 1-hour average PM_{10} concentration exceeded 300 $\mu g/m^3$. The sample duration was set for a minimum of two hours and a maximum of eight hours. The sample filter cassette was subsequently

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analyzed for PM_{10}, metals using XRF[3] instrumentation and sulfate using ion chromatography. These data are limited to five sampling events, as only 17 of 8,760 hours from February 2007 through March 2008 had air with PM_{10} concentrations exceeding 300 µg/m^3.

3.1.3   Meteorological Data

Meteorological parameters measured during the entire AQM program consisted of wind speed and direction, precipitation, temperature, relative humidity, solar radiation, and barometric pressure. Wind speeds were reported as 15 minute and hourly averages. Meteorological data was collected from January 2005 through December 2006 from the meteorological station at Pumpback Well PW-06 (near AM-6). During January 2007, the meteorological station was moved from its original location to AM-6 and the wind sensor was elevated on a newly constructed 10-meter tower. Wind sensors were also installed on newly constructed 10-meter towers at locations AM-1 and AM-3. Meteorological data was then collected from February 2007 through March 2008 at AM-1, AM-3, and AM-6. Although the AQM program has ended, the meteorological station at AM-6 continues to operate in support of other Site activity.

3.2   Evaluation of AQM Data

This section summarizes the evaluation of the AQM data including wind speed and direction, correlation of 24-hour average and hourly average PM_{10} concentrations, comparison of 24-hour average PM_{10} and TSP results, dust event results, and comparison of upwind and downwind concentrations.

3.2.1   Wind Direction Data

Figure 3-2 provides a wind rose for over 100,000 wind speed and direction measurements from January 2005 through December 2007. Based upon analysis of the wind rose, wind direction is variable at the Site with no quadrant representing over 50 percent of the total measurements. When wind speed is above 20 mph, a predominant wind direction from the southwest to the northeast emerges. This condition is consistent with visual observations made by local residents.

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[3] XRF refers to X-ray fluorescence spectroscopy

3.2.2   Wind Speed Data

Wind speed measurements during the AQM program ranged from 0.0 to 52.5 mph, with the maximum value recorded at AM-6 at 13:15 on June 5, 2007 during a "dust event". Typically, the highest average monthly wind speeds were measured during the months of April, May, and June. Approximately 85 percent of the total measurements were less than 10 mph. Wind speeds in excess of 20 mph represented less than four percent of the measurements.

3.2.3   Correlation of Hourly Average PM_{10} Concentrations with Wind Speed

The correlation of hourly PM_{10} concentration with hourly wind speed was calculated for each location. The correlations (R^2 values) ranged from 0.13 to 0.27 indicating a poor correlation for the data sets. This suggests that other factors influence the measured PM_{10} concentrations such as other emission sources beside wind erosion, and other variables such as precipitation and soil moisture. However, when a subset of the hourly PM_{10} concentration data is selected for those hours with wind speeds greater than 20 mph, the correlations improve (R^2 between 0.54 and 0.71). Therefore, the better correlation with the high wind speed data subset suggests that the contribution of wind erosion emissions to measured PM_{10} concentrations increases in importance (relative to other emission processes) as the wind speeds increase.

3.2.4   Comparison of 24-Hour Average and Hourly Average PM_{10} Concentrations

Beginning in February 2007, locations AM-1, AM-3 and AM-6 each had a high volume 24-average concentration PM_{10} sampler and a continuous hourly PM_{10} sampler and these can be considered co-located samplers. The relative percent difference (RPD) of 24-hour average and hourly PM_{10} concentrations was calculated at the three monitoring locations. The average RPD was between 25 and 27 percent. However, when a subset of the particulate measurements is selected for PM_{10} concentrations above 15 $\mu g/m^3$, RPD values improved and ranged from 12 to 19 percent. The correlation of 24-hour average and hourly average concentrations was calculated for each location. The correlations (R^2 values) ranged from 0.86 to 0.98, indicating an excellent correlation for these data sets.

3.2.5   Correlation of 24-Hour Average TSP and PM$_{10}$ Concentrations

The correlation of gravimetric TSP concentrations with gravimetric PM$_{10}$ concentrations (PM$_{10}$ data are a subset of TSP data) was calculated for AM-1 through AM-6. The correlations between TSP and PM$_{10}$ results range from 0.83 to 0.92, indicating an excellent correlation at all monitoring locations. Therefore, TSP concentrations at a given location can be estimated with good confidence from PM$_{10}$ concentrations. On average, PM$_{10}$ concentrations during the AQM program measured at all locations at the Site represented between 40 and 46 percent of TSP concentrations, which agrees well with the typical percentage previously reported by EPA of 48 percent (EPA, 1986).

3.2.6   Dust Event Data

Based on visual observations and collected data during the 3-year AQM program, about five "dust events" per year occur at the Site. "Dust events" are relatively short term occurrences (e.g. 2 to 8 hours), and are usually associated with a combination of high winds and dry conditions. The evaluation of "dust events" was approached in two ways. First, dust events in 2005-2006 were based on visual observations by local residents ("observed dust events") and second, dust events in 2007 were based on periods when hourly PM$_{10}$ concentrations exceeded 300 µg/m^3 at AM-6 ("sampled dust events").

2005-2006 Observed Dust Events

Based on visual observations, local residents reported four dust events in 2005 and seven events in 2006. The meteorological data from the Site include wind speed data for all these "observed dust events". The 11 "observed dust events" reported in 2005 and 2006 are summarized below, including wind speed statistics for the observed dust event days. Because the 24-hour high volume samplers operating on the NAAQS 6-day schedule captured five of the 11 "observed dust events" (three of the four events in 2005 and two of the seven events in 2006), analytical data are available for these five "observed dust events".

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Peak 15-minute wind speeds during these events ranged from 12.46 to 49.3 mph. The 24-hour average concentrations of PM_{10} ranged from 3.86 to 38.25 µg/m³. The 24-hour high volume PM_{10} concentrations can be conservatively adjusted to hourly PM_{10} concentrations by multiplying by 24 (this adjustment assumes that all material collected during the 24-hour sampling period was collected during a one hour period, and represents the upper bound for the one hour concentrations). The adjusted hourly PM_{10} concentrations for the five 2005-2006 "observed dust events" characterized by high volume sampling ranged from 93 to 918 µg/m³.

Table 3-1. 2005-2006 Dust Events Observed and Reported by the Community							
	Wind Speed (mph)				24-Hour Average High Volume Air Samples		
Date	Min.	Avg.	Max.	Std. Dev.	Sampling Event #	Max. 24-Hour PM_{10} (µg/m³)	Adjusted 1-Hour PM_{10} (µg/m³)
3/5/05	0.12	4.46	12.46	2.98	7	5.42	130
6/21/05	1.09	12.33	34.92	10.79	25	18.12	435
6/27/05	0.55	5.99	17.43	4.50	26	10.00	240
12/1/05	9.45	35.15	49.30	10.90	Not Captured		
1/30/06	1.67	14.34	40.91	13.84	Not Captured		
2/4/06	1.44	15.13	33.50	11.70	63	38.25	918
3/6/06	1.10	6.54	16.82	3.79	68	3.86	93
3/25/06	2.55	20.50	36.03	9.23	Not Captured		
4/7/06	0.47	10.76	33.48	10.94	Not Captured		
4/15/06	4.53	19.69	35.60	8.18	Not Captured		
8/14/06	0.22	5.68	20.11	4.64	Not Captured		

2007 Sampled Dust Events

The following table summarizes the five 2007 sampling events that were collected because the hourly average PM_{10} concentrations at AM-6 exceeded the trigger level of 300 µg/m³.

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						Maximum Hourly	Maximum Hourly
Table 3-2. 2007 Dust Events Triggered by Hourly Average PM$_{10}$ Values							
Event	**Date**	**Start Time**	**Stop Time**	**XRF Sample Duration / Volume**	**Maximum Hourly Average PM$_{10}$ (µg/m^3)**	**Maximum Hourly Wind Speed During Event (mph)**	**Maximum Hourly Wind Speed Entire Day (mph)**
1	3/21/07	08:00	10:00	2 hours / 1.64 L	435	13	13
2	5/25/07	05:00	07:00	2 hours /1.64 L	331	8.4	16
3	6/5/07	11:00	15:00	2 hours[1] / 1.60 L	1,200[2]	45	45
4	8/17/07	07:00	09:00	2 hours / 1.64 L	375	2.5	20
5	9/19/07	06:00	08:00	2 hours / 1.64 L	324	4.8	22

Notes: (1) Power outages terminated the ACCU sample prematurely. 'Dust event' duration was approximately 4 hours.
(2) Estimated due to power outage.

The June 5, 2007 "observed dust event" had the highest hourly average PM$_{10}$ concentrations and wind speeds and is discussed in more detail. This "sampled dust event" was regional and affected not only the Mason Valley air basin, but distant air basins such as the Carson Valley and Carson City (discussed in more detail in Section 3.6.2).

The days leading up to June 5, 2007 were hot and dry with daily highs of 90°F, relative humidity at 40-60 percent, and no precipitation within the previous 30 days. On June 5, 2007, strong winds blew persistently from the southwest to the northeast, with a peak 15-minute wind speed of 53 mph, which was the highest speed measured during the 3-year AQM program.

High winds caused three brief power outages (lasting approximately 15 to 90 seconds each) that occurred at approximately 11:13 am, 11:50 am, and 1:05 pm. The meteorological stations were not affected since they have internal battery backup. The high volume PM$_{10}$ air samplers were not significantly affected since they restarted after the power outages. The continuous hourly average monitors reset after each power outage, which resulted in the loss of three hours of data during the event: 12:00 pm, 1:00 pm and 2:00 pm. All types of data were collected during the June 5, 2007 "sampled dust event" (24-hours average and hourly average concentrations of PM$_{10}$ and XRF metals when dust levels exceeded the trigger level and meteorological data).

Table 3-3. Hourly PM$_{10}$ During Core Dust Event Hours			
Standard Time[1]	AM-1 Hourly PM$_{10}$ (µg/m^3)	AM-3 Hourly PM$_{10}$ (µg/m^3)	AM-6 Hourly PM$_{10}$ (µg/m^3)
06:00	13.7	14.1	16.8
07:00	14.7	11.5	13.1
08:00	14.8	14.4	15
09:00	61.4	53.7	64.4
10:00	194.3	510.8	256.7
11:00	140.7	750.6	820
11:13	Brief Power Outage (approx. 15 seconds)		
11:50	Brief Power Outage (approx. 90 seconds)		
12:00	200[1]	800[1]	1,000[1]
13:00	300[1]	900[1]	1,100[1]
13:05	Brief Power Outage (approx. 15 seconds)		
14:00	400[1]	1,000[1]	1,200[1]
15:00	72.2	164.6	147.7
16:00	33.6	32.6	33.8
17:00	16.8	23	17.9
18:00	14.3	8	8.3

Note: (1) Value estimated due to power outage

3.4   Upwind/Downwind Evaluation

An upwind/downwind evaluation and statistical analysis was performed to determine any difference in concentrations between downwind and upwind monitors that represent the contribution of Site emissions to the total downwind concentration.

This section presents an upwind/downwind statistical evaluation of the 24-hour average data followed by a comparison of these data to regional 24-hour average data. A statistical evaluation of the hourly average PM$_{10}$ was also conducted. The "sampled dust event" data of June 5, 2007 are also discussed although the limited data set, i.e. one data point per chemical per upwind and downwind station, precludes a statistical comparison.

3.4.1   24-Hour Average (High Volume) Chemical Data

The upwind/downwind evaluation of 24-hour high volume data is most meaningful if data are used from monitoring days with a predominant wind direction. These "predominant wind days" are more likely to produce a measurable difference between upwind and downwind results. A monitoring day was defined to have a predominant wind direction when at least 50 percent of the 96 individual 15-minute wind direction measurements occurred in one 90 degree quadrant (the quadrants are overlapping 90 degree arcs).

This approach resulted in the creation of a subset of the 24-hour average concentration data set, which included the days with the maximum PM_{10} results and the maximum daily wind speeds observed during the monitoring program. The upwind/downwind stations were assigned based on the 90-degree quadrants.   The process used to statistically analyze 24-hour average concentration sampling data for the purpose of comparing upwind/downwind concentrations is described below.

1. Data from the northeast and south quadrants were selected for further evaluation. The remaining quadrants had five or fewer sampling events, which did not provide enough data for a meaningful statistical analysis.

2. Sampling events with no nondetect measurements were identified for further evaluation. Statistical procedures that were used for this evaluation could produce inaccurate results in the presence of nondetect values. This is particularly true when detection limits are variable or elevated as they are with the high-volume air sampling data used to collect the 24-hour average concentrations.

3. Analytes with at least eight events with no nondetect measurements were chosen for the statistical analysis.   A minimum of eight data points was required for the upwind/downwind analysis.

4. For each sampling event, the minimum, maximum and mean concentrations were determined for upwind and for downwind.

5. Data were prepared for three scenarios. Those are (1) minimum upwind and maximum downwind ("worst case" scenario), (2) maximum upwind and minimum downwind ("best case" scenario), and (3) mean upwind and mean downwind.

6. Upwind concentrations were subtracted from downwind concentrations to prepare the data for analysis by the sign test. The sign test is an appropriate statistical method for analyzing paired data that are non-normal and asymmetrical, which is the case for these data. The sign test is also a suitable method for the small sample sizes analyzed for this evaluation.

7. The sign test was applied to data for each of the three scenarios.

8. Results from Scenario 3, which compare mean upwind and mean downwind concentrations, were deemed the most accurate for the upwind/downwind comparison. Those results are summarized in the table below, which gives the estimated median differences and the statistical significance of the medians.

9. Confidence intervals for the median differences were calculated and plotted for each of the three scenarios. The confidence intervals indicate the uncertainty in estimates of the median.

Table 3-4. Sign Test Results for Differences in Median Upwind and Median Downwind Concentrations Using 24-Hour High Volume Sampling Measurements

Analyte	Quad.	Type of Moni-toring	No. of Obser.	Median Upwind ($\mu g/m^3$)	Median Difference (Down. – Up.) ($\mu g/m^3$)	Is Median Difference Statistically Significant?	Median Downwind ($\mu g/m^3$)	Median Difference / Mean Upwind x 100	Median Difference / Mean Downwind x 100
Aluminum	NE	PM_{10}	17	0.0934	0.0376	yes	0.131	40	29
Aluminum	NE	TSP	11	0.313	0.00158	no	0.315	0.50	0.50
Cadmium	NE	PM_{10}	10	4.91E-5	8.46E-7	no	5.0E-5	1.7	1.7
Copper	NE	PM_{10}	24	0.00726	0.00364	yes	0.0109	50	33
Copper	NE	TSP	12	0.0545	5.88E-4	no	0.0551	1.1	1.1
Copper	South	PM_{10}	9	0.00897	0.00693	yes	0.0155	77	45
Copper	South	TSP	8	0.0452	0.00749	no	0.0527	17	14
Manganese	NE	PM_{10}	22	0.00507	2.59E-4	no	0.00533	5.1	4.9
Manganese	NE	TSP	11	0.0125	-0.00157	no	0.0109	-13	-14
PM10	NE	PM_{10}	24	8.26	1.84	yes	10.1	22	18
PM10	South	PM_{10}	11	4.85	0.221	no	5.07	4.6	4.4
Sulfate	NE	PM_{10}	9	0.737	0.0430	no	0.78	5.8	5.5
TSP	NE	TSP	12	19.9	2.65	no	22.5	13	12

The upwind/downwind evaluation indicated that Scenario 3 is, statistically, the most robust scenario. For Scenario 3, four of the 13 datasets show that median concentrations are statistically higher downwind than upwind for the following parameters: aluminum, copper (for two quadrants) and PM_{10}. For wind blowing to the northeast quadrant, this indicates that concentrations of PM_{10}, aluminum and copper are higher at the downwind Site fenceline. For the nine data sets that were not statistically significant, the median differences (i.e., Site contributions) for all analytes are low i.e., less than 14 percent difference, when compared to the corresponding downwind concentrations.

3.4.2   Regional Data Comparison

The Site is located in the Mason Valley, a rural area with a moderately low population, and agricultural and past mining activities. ARC conducted a search for available regional air quality data that is representative of rural areas influenced by agricultural and mining operations, for comparison to the Site upwind concentration data presented in the previous sections. PM_{10} was the only type of data collected at the Site that was found in other regional databases. There was no recent TSP data available for comparison, and no metals or radiochemical data were found. State and local air agencies and industry do not typically perform the metals and radiochemical laboratory analyses that have been conducted by ARC. Therefore, this regional background analysis focuses on PM_{10} data.

There are a limited number of PM_{10} monitors operated by NDEP, Washoe County, or industry in Nevada that are representative of conditions in Mason Valley, as many of the monitors are sited in urban areas and used to determine population exposure. The PM_{10} monitoring locations that may be used to evaluate regional background PM_{10} concentrations at rural areas potentially impacted by agricultural and mining operations are described below.

- Sierra Pacific Ft. Churchill Monitoring Location: operated by Sierra Pacific in 1996 and 1997 to collect PM_{10} data to support the air permitting of a new electrical power generator. The objective of the monitoring was to collect regional background PM_{10} data for use in air quality analyses. Given the close proximity of this monitoring location to the Site, it is representative of background conditions at the Site.

- NDEP Linda Monitoring Location: located in a small rural residential area on the edge of Pahrump in southeastern Nevada, this regional background monitoring location adjoins rural areas with native desert vegetation. There are gravel roads in the area, but they experience little traffic. The period of operation is from May 2003 to present.

- NDEP Fallon Monitoring Location: located in a residential neighborhood that may at times be affected by agricultural operations surrounding the town. PM_{10} sampling commenced at this location in May 1993 and was discontinued at the end of June 1998.

- NDEP Fernley Intermediate School Monitoring Location: located in an area of residential and agricultural use and recent industrial growth. Sampling for PM_{10} at this location commenced in May 1995 and was discontinued in November 1998.

- NDEP McGill Monitoring Location: located near Ely Nevada, this monitoring location is in a residential area near a closed mining operation. The town is potentially subject to blowing dust from mine tailings. PM_{10} sampling commenced at this location in June 1993 and was discontinued at the end of March 1998.

The PM_{10} concentration data from these background monitoring locations and the Site upwind and downwind data set are summarized and compared in the following table. Note that the data sets are not from concurrent time periods, and some variability in regional background concentrations is expected caused by annual variations in wind and precipitation patterns. The Site upwind 24-hr PM_{10} data set consists of forty eight days when there was a predominant 24-hr wind direction that resulted in the determination of upwind concentrations.

Overall, the regional/background data are similar to Site data. The typical annual mean PM_{10} concentrations range from 11 to 28 $\mu g/m^3$ and the maximum 24-hr PM_{10} concentrations range from 46 to 175 $\mu g/m^3$. The Site upwind data fall within the lower range of the regional/background concentrations. Note that the Site maximum downwind concentration of 166 $\mu g/m^3$ is lower than the maximum of 175 $\mu g/m^3$ measured among the regional monitoring locations. In summary, this general data comparison indicates that the Site maximum upwind and downwind data sets fall within typical regional/background PM_{10} concentration ranges.

Table 3-5. Summary of PM_{10} Results at Regional/Background Monitoring Locations ($\mu g/m^3$)		
Monitoring Location	**Mean of Annual Average Concentrations**	**Max. 24-hr Concentration During Entire Data Period**
Ft. Churchill	11	46
Yerington Mine Upwind	11	87
Yerington Mine Downwind	14	166
Linda (near Pahrump)	15	175
McGill	16	149
Fernley	18	104
Fallon	28	111

3.4.3 Hourly Average PM$_{10}$ Data

The upwind/downwind evaluation consisted of three steps: 1) determining the predominant wind direction for each hour at each station; 2) designating upwind/downwind stations ("couples") based on the wind direction in 30-degreee arcs; and 3) comparing the upwind/downwind results. Note that this approach resulted in the creation of a subset of the entire hourly continuous PM$_{10}$ data set. The process used to statistically analyze the resulting hourly PM$_{10}$ upwind/downwind data sets is outlined below.

1. The upwind/downwind data subset was further divided into six groups. Hours with the same upwind and downwind station pairs or "couples" were grouped together.
2. Upwind concentrations were subtracted from downwind concentrations to prepare the data for analysis by the paired t-test.
3. The paired t-test was applied to the six sets of downwind minus upwind concentration differences.
4. Confidence intervals for the mean differences were calculated and plotted for the six groups of data. The confidence intervals indicate the uncertainty in estimates of the mean.

Statistical hypothesis testing only provides information regarding the probability that the true mean difference is (or is not) equal to zero (hypothesis testing does not provide information regarding the practical significance of a calculated mean difference). The mean difference may be statistically significant, but not practically significant because of a low magnitude of the mean difference relative to the total background concentration. Five of the six cases presented below show that hourly PM$_{10}$ measurements are statistically higher downwind than upwind.

Table 3-6. Paired T-test Results for Differences in Upwind and Downwind Concentrations of PM$_{10}$ Using Hourly Sampling Measurements

Case	Up-wind Station	Down-wind Station	No. of Observ.	Mean Upwind (µg/m^3)	Mean Difference (Downwind - Upwind) (µg/m^3)	Is Mean Difference Statistically Significant?	Mean Downwind (µg/m^3)	Mean Difference / Mean Upwind x 100	Mean Difference / Mean Downwind x 100
1	AM-1	AM-3	526	15.69	7.71	Yes	23.4	49	33
2	AM-3	AM-1	147	13.42	2.68	Yes	16.1	20	17
3	AM-1	AM-6	193	8.29	2.61	Yes	10.9	32	24
4	AM-6	AM-1	254	11.23	1.67	Yes	12.9	15	13
5	AM-3	AM-6	378	11.16	3.34	Yes	14.5	30	23
6	AM-6	AM-3	352	11.5	-0.200	No	11.3	-2	-2

The mean downwind/upwind differences (i.e., contributions from the Site) can be compared to mean upwind and mean downwind concentrations. Site-related PM$_{10}$ concentrations, on average, represent a 15 to 49 percent increase compared to upwind PM$_{10}$ concentrations. Site-related PM$_{10}$ concentrations, on average, contribute approximately 13 to 33 percent of the total downwind PM$_{10}$ concentrations (background sources contribute the remaining amounts).

A second statistical analysis of the hourly PM$_{10}$ upwind/downwind data set was performed to determine if the increase in the downwind PM$_{10}$ concentrations was affected by wind speed. The upwind/downwind data sets were further processed to compile only those upwind/downwind data couples with wind speeds greater than 20 mph at either of the paired stations. The same statistical analyses were then performed, but only one of the cases resulted in a statistically significant mean difference as shown in the following table.

Table 3-7. Paired T-test Results for Differences in Upwind and Downwind Concentrations of PM$_{10}$ Using Hourly Sampling Measurements when Wind Speed is greater than 20 mph

Case	Up-wind Station	Down-wind Station	No. of Observ.	Mean Upwind (µg/m^3)	Mean Difference (Downwind - Upwind) (µg/m^3)	Is Mean Difference Statistically Significant?	Mean Downwind (µg/m^3)	Mean Difference / Mean Upwind x 100	Mean Difference / Mean Downwind x 100
1	AM-1	AM-3	138	27.5	28.3	Yes	55.8	103	50.7

Based on the analysis of this data set, the relative contributions from Site sources to downwind PM_{10} concentrations increases as the wind speeds increase beyond 20 mph. The Site contribution percentages for the "all upwind/downwind" data set range from 13 to 33 percent. However, for the higher wind speed data subset, the Site contribution is 51 percent.

In summary, the upwind /downwind analysis of hourly PM_{10} concentration data indicates that Site PM_{10} emissions have migrated off-Site and, on average, contribute approximately 13 to 33 percent of the measured downwind PM_{10} concentrations (background sources contribute the remaining amounts). When wind speeds exceed 20 mph (which occurred in fewer than 4 percent of the wind speed measurements), the Site contribution to downwind PM_{10} concentrations increases to approximately 51 percent with background and Site sources contributing equally. Restated with respect to upwind PM_{10} concentrations, the Site PM_{10} contribution represents a 103 percent increase during high wind periods. These results are consistent with the upwind/downwind analysis of PM_{10} concentrations for the June 5, 2007 "sampled dust event".

3.4.4   June 5, 2007 "Sampled Dust Event"

An upwind/downwind evaluation was performed for the June 5, 2007 "sampled dust event" data because it produced maximum values of PM_{10} and several metals during the 3-year AQM program. The maximum high-volume 24-hour average PM_{10} downwind concentration was 166 $\mu g/m^3$, and the corresponding upwind concentration was 87 $\mu g/m^3$. The "sampled dust event" upwind/downwind analysis also evaluated the 24-hour average chemical data by calculating the upwind mass ratio of chemicals to PM_{10}, the downwind mass ratio of chemicals to PM_{10}, and a relative "enrichment factor", which compares the two mass ratios (an enrichment factor greater than 1 indicates that the downwind concentration for this event was greater than the upwind concentration). Relative enrichment factors greater than 1 were calculated for arsenic, cadmium, cobalt, copper and some radiochemicals.

SECTION 4.0

CHRONIC (LONG-TERM) HUMAN HEALTH RISK ASSESSMENT

A baseline chronic risk assessment evaluates the potential that inhalation of dust and associated chemicals and radiochemicals in the air poses a concern to human health over the long term (i.e., a person's lifetime). "Baseline" means that the risk assessment evaluates current conditions as if these conditions remain unchanged for the next 30 years. The purpose of this chronic HHRA is to determine the risks at the Site boundary and to determine if releases of particulates from the Site result in an increase in the health effects above the background risk from other sources.

A chronic risk assessment does not predict actual health effects but is an estimate of the likelihood that exposure (under the conditions assumed in the risk assessment) will lead to adverse health effects in all populations including sensitive population such as children or the elderly (EPA, 2004). EPA has explicitly stated that any actual risk may be as low as zero (EPA, 2004). The long-term or lifetime risk assessment methods were developed by EPA as one tool in making decisions determining whether action is warranted to reduce exposure from a release from a site (EPA 1989; 2004; 2009). EPA developed this methodology with the best available science and is continuously updating these methods as new scientific research becomes available. In areas without sufficient science, EPA makes policy decisions to fill the gap. The EPA methodology is designed to assure that the actual risk, if any is present, will not be underestimated.

The formal risk assessment process consists of the following five steps:

- Data Evaluation - discusses the data that are available for inclusion in the chronic risk assessment.
- Exposure Assessment - presents the receptors and exposure pathways and explains how exposure is estimated.
- Toxicity Assessment - presents the toxicity factors used to estimate the potential health effects associated with each dose.

- Risk Characterization - shows how the information in the Exposure and Toxicity Assessments is combined to estimate the potential for adverse health effects.

- Uncertainty Analysis - discusses the level of confidence that can be placed in the results of the chronic risk assessment.

4.1   Data Evaluation

All the parameters included in the 24-hour average concentration (high volume) PM_{10} samples were evaluated to identify the chemicals of potential concern for lifetime risk (chronic COPCs). A summary of the 24-hour average concentrations data is presented on Table 4-1. There are 32 parameters for all six air monitoring stations including PM_{10}, 21 metals, sulfate and nine radiochemical parameters. Summaries for each of the air monitoring stations are presented in Appendix A.

Five parameters were not included as chronic COPCs. Calcium, magnesium and sodium are not included in long-term chronic health assessments per EPA guidance because these chemicals are essential nutrients (EPA, 1989). Gross alpha and beta measurements are not included because these measurements are not specific to any one radiochemical but capture all radiochemicals that emit alpha or beta emissions. The individual radiochemicals which make up the gross alpha and beta measurements are included as chronic COPCs.

The chemicals and radiochemicals associated with PM_{10} are used in this chronic risk assessment because this size fraction of the particulate matter is respirable. PM_{10} is considered the appropriate fraction of particulate matter for the protection of human health because these small particles penetrate most deeply into the lungs. A table of similar information for the TSP samples is included in Appendix A; however, these data are not including in the chronic risk assessment.

Twenty-seven chemicals (metals and sulfate), radiochemicals and PM_{10} are included as chronic COPCs. The majority of parameters (52 percent) have more than 700 samples and an additional 41 percent have more than 500 samples. Mercury has 400 samples and sulfate has 193 samples. The following is a list of the chronic COPC in groups based on frequency of detection:

- Seven chronic COPCs were reported in greater than 80 percent of the samples in decreasing order of frequency: PM_{10}, copper, lead, manganese, sulfate, aluminum and iron.

- Twelve chronic COPCs were reported in between 54 and 7 percent of the samples in decreasing order of frequency: cadmium, zinc, mercury, beryllium, silver, thorium-230, nickel, radium-228, radium-226, vanadium, chromium and arsenic.

- Eight chronic COPCs were reported in two percent or fewer of the samples including molybdenum, thorium-228, uranium-234, selenium, cobalt, thorium-232, barium and uranium-238.

4.2 Exposure Assessment

The exposure assessment develops estimates of the concentrations at the air monitoring stations that are designed to not under-estimate concentrations that a receptor might inhale on a daily basis. The potential Site sources of dust and exposure pathway evaluated in this HHRA are shown on Figure 4-1. The assumptions and equations used in the calculation of exposure are presented on Table 4-2.

4.2.1 Exposure Concentrations

Exposure point concentrations were calculated for each air monitoring station as well as for all stations combined. For chronic risk, EPA guidance recommends using an average concentration most representative of the long-term exposure (i.e., 30 years). Because it is not possible to know the true average, EPA guidance recommends using an upper confidence limit (UCL) of the average concentration.

An exposure concentration was calculated for each COPC at each air monitoring station and the combined data set using EPA's ProUCL software, Version 4.00.04 (EPA, 2009b). ProUCL calculates UCLs for a range of distributions of the data and recommends the most appropriate UCL based on the best fit to a distribution. If the recommended UCL exceeds the maximum concentration detected, ProUCL recommends that the maximum concentration be used to represent the exposure concentration (EPA, 1989). The exposure concentrations for all air monitoring combined and for the individual air monitoring stations are presented in Appendix A.

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All chronic COPCs were assumed to be present at each air monitoring station even if only reported at some of the stations. For example, cobalt was not reported at AM-4 and AM-5 but was assumed to be present at these locations at the concentrations developed based on the data for all stations. This approach is conservative because it is possible that cobalt is present at these locations but the concentration was below the detection limit.

4.2.2 Daily Intake Concentration for Chemicals

Daily intake concentration used to calculate exposure for chemicals is the time-weighted average concentration. The exposure concentration is adjusted to reflect the amount of time that a resident is exposed (EPA, 2009a). Using standard EPA assumptions for residential exposure, a hypothetical resident is assumed to spend 30 years at each air monitoring station, breathing the outdoor air 24 hours per day for 350 days per year (EPA, 2009c). In accordance with EPA guidance, children and adult exposure is considered in this calculation and no adjustment is made based on age. The equation for calculating intake for chemicals is shown below:

$$IC = (C \times ET \times EF \times ED) / (AT)$$

where

IC	=	intake concentration (mg/m^3) for chemicals
C	=	exposure point concentration (milligrams per cubic meter of air)
EF	=	exposure frequency (days per year)
ET	=	exposure time (hours/day per 1 day/24 hours)
ED	=	exposure duration (years)
AT	=	averaging time (days)

4.2.3 Intake for Radiochemicals

Radiochemical intake is calculated in terms of the amount of radioactivity and has units of inhaled picocuries (pCi). Radiochemical intake is adjusted for age. Separate inhalation rates for six years as a child and 24 years as an adult are shown on Table 4-2. The equation for calculating intake for radiochemicals is:

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$$I = (C \times IR \times EF \times ED)$$

where

I	=	intake (pCi) for radiochemicals
C	=	exposure point concentration (pCi per cubic meter of air)
IR	=	inhalation rate (cubic meters of air per day)
EF	=	exposure frequency (days per year)
ED	=	exposure duration (years)

4.3   Toxicity Assessment

The toxicity assessment identifies toxicity factors which describe the relationship between the daily intake and the potential for a health effect. Toxicity factors are developed from studies that show the relationship between exposure to a chemical or radiochemical and the resulting health effects. The toxicity factors for chemicals are generally based on studies in animals although some toxicity factors are based on studies on people exposed to high levels of the chemical in an occupational setting. The toxicity factors used in this chronic HHRA are presented on Table 4-3.

Toxicological effects fall into two categories: 1) effects that could potentially cause cancer (carcinogenic); and 2) effects that could cause other types of adverse health effects (noncarcinogenic or systemic). Summaries of the toxicological effects associated with the chronic COPCs prepared by the Agency for Toxic Substances and Disease Registry are included in Appendix B.

For chemicals, the toxicity value for carcinogenic effects is called an inhalation unit risk factor (IUR) with units of $(\mu g/m^3)^{-1}$, and the toxicity value for noncarcinogenic effects is called a reference concentration (RfCi) in mg/m^3. Chemicals that show a potential for both carcinogenic and noncarcinogenic health effects are assigned both inhalation unit risk and reference concentrations. The toxicity factor for radiochemicals is a cancer slope factor with risk per picocurie (risk/pCi). In accordance with EPA guidance, radiochemicals are only assessed for the potential to increase incidence of cancer. For radiochemicals, the only source of toxicity factors is the Health Effects Assessment Summary Tables for Radionuclides (EPA, 2001).

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The hierarchy of human health toxicity values follows OSWER Directive 9285.7-53, issued by EPA's Office of Solid Waste and Emergency Response on December 5, 2003, as augmented in the EPA Regional Screening Levels (EPA, 2009c):

1. EPA's Integrated Risk Information System (IRIS).
2. The Provisional Peer Reviewed Toxicity Values (PPRTVs) derived by EPA's Superfund Health Risk Technical Support Center for the EPA Superfund program.
3. The Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (MRLs).
4. The California Environmental Protection Agency/Office of Environmental Health Hazard Assessment's toxicity values (http://www.oehha.ca.gov/risk/ChemicalDB/index.asp).
5. The EPA Superfund program's Health Effects Assessment Summary (EPA, 1997).

Toxicity values from Source 2 were obtained from the table of regional screening levels (RSLs) published by EPA because PPRTVs are not available to the public (EPA, 2009c). The carcinogenic toxicity value of chromium was adjusted to account for the possible presence of hexavalent chromium. There are two forms of chromium, trivalent and hexavalent. Trivalent chromium is the more stable form, most common in the environment and is not considered a potential carcinogen. The hexavalent form, while not as stable in the environment, is considered to be a Group A, or known human carcinogen via inhalation. There is no analytical method for analyzing the air samples for hexavalent chromium because of the unstable nature of this form of chromium. To represent a conservative assessment of any potential risk from this form, EPA Region 9 recommends assuming that $1/7^{th}$ of the total chromium is in the hexavalent form (EPA, 2004).

The following is a discussion of COPCs that do not have toxicity values in Table 4-3 and how the evaluation of the health effects was addressed.

There are five chronic COPCs (copper, iron, molybdenum, silver and zinc) that do not have either a cancer or a noncancer toxicity factor in these sources via the inhalation pathway. EPA guidance is to contact EPA to request inhalation toxicity factors (EPA, 2009a). EPA did not have inhalation toxicity values available. EPA does not consider any of these metals potential

carcinogens so the appropriate toxicity value is an inhalation reference concentration. EPA Region 9 suggested converting the oral reference doses for these metals into inhalation reference concentrations (route-to-route extrapolation) rather than exclude these metals from the HHRA. In the past, EPA Region 9 has used route-to-route extrapolation for some organic chemicals but generally not for metals (EPA, 2004). The toxicological properties of these metals have been well studied. The absence of an inhalation toxicity factor likely indicates an absence of long-term systemic health effects via inhalation of environmental levels (as opposed to high occupational levels). Nevertheless, the possibility that these metals may exert some systemic effect is evaluated quantitatively in Section 6, Uncertainty Analysis.

Sulfate was not included in the chronic HHRA because sulfate does not have a chronic toxicity factor. Sulfate is primarily known for acute health effects and is not associated with chronic health effects. Sulfate is a common ingredient in foods, vitamins and medicines as many compounds are used in the form of sulfate salts. ATSDR has not prepared a toxicological profile. However, more information is available at http://www.epa.gov/safewater/contaminants/unregulated/sulfate.html.

In accordance with EPA guidance, evaluation of the health effects of PM_{10} and lead are done by comparison to National Ambient Air Quality Standards for these chronic COPCs. These parameters are not assigned toxicity values or included in the quantitative calculation of cancer and noncancer health effects.

4.4   Risk Characterization

The final step in any risk assessment is to combine daily intake and toxicity values to calculate potential cancer risks for chemicals and radiochemicals, noncancer health estimates for chemicals, and the evaluation of lead and PM_{10} results.

4.4.1   Cancer Risk

This section presents the methods and results for the cancer risk calculations for chemicals that are considered potential carcinogens and all radiochemicals.

Methods

Cancer risk represents the probability that exposure to chronic COPCs could result in an increased risk of cancer. Cancer risk is termed "the probability of increased individual excess cancer" (i.e., the risk over and above the natural risk of cancer in the general public). The EPA considers cancer risks at or below 1×10^{-6} (also written as 1 E-06) to be insignificant. EPA has defined risks between 1×10^{-6} and 1×10^{-4} as the risk management range. In accordance with EPA guidance, cancer risks up to 1×10^{-4} can be considered acceptable.

"Cancer risk", as determined with the EPA risk assessment methodology, is a hypothetical probability and is not based on actual cases of cancer. The cancer risk numbers reported in this chronic HHRA are not based on a statistical evaluation of cases of cancer in people exposed to relatively low doses of chemicals and radiochemicals such as found in the air at the Site.

Chemical cancer risk is calculated by multiplying the daily intake concentrations times the unit risk factor as follows:

Chemical cancer risk = daily intake concentration × unit risk factor

Radiochemical cancer is calculated by multiplying the intake times the cancer slope factor as follows:

Radiochemical cancer risk = intake for radiochemicals × cancer slope factor

The total cancer risks are added across chemicals and radiochemicals to estimate an overall cancer risk. The total cancer risk includes chemicals and radiochemicals that are found at or below background concentrations.

Results

The cancer risks (including chemicals present at background concentrations) range from 1 E-04 to 3 E-05 for all stations and the individual stations (Table 4-4). These cancer risks are within the EPA risk management range.

The range of cancer risks among air monitoring stations AM-1, 2- 3, 4, and 6 is small, from 3 E-05 to 5 E-05. Given the uncertainty associated with cancer risk estimates (See Section 4.6), it is unlikely that there is any significant difference in these risks. The slightly higher total risk at AM-5 to 1 E-04 is due to chromium with a risk of 9 E-05, which is higher than the total risk at the other locations. This risk is based on the single positive result for chromium at AM-5. Chromium was reported in only 1 of 82 samples at AM-5 and so the maximum concentration of chromium was used to calculate the risk. Therefore, the difference between the cancer risk at AM-5 and the other locations results from a single data point rather than am actual increase in air concentrations at this location. As discussed in Section 4.3, the cancer risk for chromium is based on the assumption that $1/7^{th}$ of the chromium is in the more toxic hexavalent form.

The cancer risk associated with cobalt is based largely on results that were below the detection limits. The analytical methods for cobalt are not able to quantify cobalt to regulatory comparison levels. Cobalt was reported in 1 percent of the samples (9 of 704 samples). Cobalt was not reported in samples from AM-4 and AM-5, but was assumed to be present at these locations using exposure concentrations from the combined data set. Therefore, the cancer risk of 6 E-06 for cobalt is based on the combined data set.

It is also noteworthy that the radiochemical COPCs also had a low frequency of detected results with the highest frequency being for thorium-230 which was found in 19 percent of the samples. Four of the radiochemicals were reported in two percent or less of the samples. This means that the cancer risk is based largely on non-detected results and the assumption that these radiochemicals are present in the air even if not reported in the sample results.

4.4.2   Noncancer Hazard Values for Chemicals and Evaluation of Lead and PM$_{10}$

This section presents the methods used to calculate noncancer hazard, the results for noncancer hazard values and the evaluation of lead and PM$_{10}$.

Methods for Noncancer Hazard

Noncancer systemic chemical health effects are evaluated based on a hazard quotient (HQ) for individual chemicals.   The HQ is the ratio between the daily intake concentration and the reference concentration:

Hazard Quotient = daily intake concentration/reference concentration

An HQ value of 1 indicates that lifetime exposure has limited potential for causing an adverse effect in sensitive populations, and values of less than 1 can generally be considered acceptable. The sum of chemical-specific HQs is called a hazard index (HI).   It is only appropriate to add HQ values for different chemicals if they have the same health effect (EPA, 1989).   Adding HQ values into a single cumulative HI value across chemicals is a preliminary estimate of the highest possible noncancer risk.   HI values of less than 1 can generally be considered acceptable.   Values greater than 1 are usually given closer attention.

Results for Noncancer Hazard

The cumulative HI values for all combined and individual air monitoring stations are equal to or less than 1 (Table 4-5).   This means that EPA considers it unlikely that these levels of exposure would result in adverse noncancer health effects over a lifetime.   Note that the HI is the sum of the individual HQ values for each chemical.   EPA guidance notes that HQ values are summed together only for chemicals that affect the same target organ.   However, it is not necessary to evaluate the potential for similar target organs because the cumulative risk is at or below 1.

The health effects of lead and PM$_{10}$ are evaluated by comparing the air concentrations to the NAAQS.   An HQ is not calculated for either parameter and the effects are not considered additive with other chemicals.   The following bullets summarize the health effects of PM$_{10}$ and lead:

- For lead, the NAAQS is a three-month rolling average. However, the maximum concentration of lead reported in any 24-hour average concentration samples was 0.0116 µg/m3which is below the NAAQS standard of 0.15 µg/m3. Therefore, no further evaluation is needed.

- For PM_{10}, the NAAQS of 150 µg/m3 is not to be exceeded more than once per year on average over 3 years. The maximum PM_{10} reported in the three years of the AQM program was 166 µg/m3 and this is the only exceedance of the NAAQS. Therefore, the PM_{10} meets the EPA standard.

4.4.3   Contribution of Background

The risks estimated in this chronic HHRA include exposure to background concentrations of chemicals. The AQM DSR (Brown and Caldwell, 2009) conducted a statistical analysis comparing the upwind and downwind concentrations as detailed in Section 3.6.1 of this report. In summary, a statistically-significant increase in the downwind concentrations was found for only three parameters (aluminum, copper and PM_{10}). Note that the frequency of detection of some of the chemicals and radiochemicals was so low that statistical comparisons were not possible. However, all the cancer risks and noncancer hazard values are acceptable. So that even if some parameters increase in concentration as the air moves across the Site, the concentrations do not present a health risk. Aluminum and PM_{10} are evaluated in this section and copper is evaluation in Section 6.

SECTION 5.0

ACUTE (SHORT-TERM) HUMAN HEALTH RISK ASSESSMENT

The evaluation of the potential for acute (i.e., short-term) health effects due to exposure to higher levels of particulates (PM_{10} and TSP), chemicals and radiochemicals is described in this section. Acute health effects are those that appear during or immediately after a short period of exposure (e.g., a few minutes to a few hours), and are generally temporary in nature (e.g., clearing up after a day or so). Examples of acute health effects include irritation to the lungs or eyes. There are four steps in the HHRA for acute health effects:

- Data Evaluation – the data are compiled and a list of the chemicals of potential concern for acute exposure (acute COPCs) is determined.
- Acute Exposure Guidelines – the exposure concentrations are compared to health-based concentrations that have been developed to be protective for short term exposure.
- Exposure Concentrations – discusses the method used to estimate the appropriate concentration of acute COPCs for comparison to the acute exposure guideline.
- Acute Risk Characterization – presents the comparison of the exposure concentration to the acute exposure guideline.

5.1   Data Evaluation

The acute COPCs include 24-hour average PM_{10}, TSP and chemical concentrations, hourly average PM_{10} concentrations, and the data collected during the "dust events". All data for the acute COPCs collected as part of the AQM program since 2005 were included in the acute HHRA. Table 5-1 presents statistics for the 24-hour average data (which is the same as used for the chronic HHRA with the addition of TSP) for all stations. Table 5-2 presents a summary of the hourly average PM_{10} data for AM-1, AM-3 and AM-6 and Table 5-3 presents a summary of the data from the "dust events" for AM-6. Note that 23 additional chemicals were analyzed for the dust event samples as compared to the 24-hour average samples.

Radiochemicals are not included as acute COPCs because short-term exposure has not been associated with acute health effects for radiochemicals, and Federal and State health agencies have not set short term guidelines for exposure to radiochemicals. Acute radiological effects are not evident until radiation doses exceeding 100 rem are received. Acute doses of this magnitude are: 1) typically only received from medical procedures, high activity gamma radiation sources, or industrial X-ray machines; and 2) are not easily achievable accidentally via inhalation, ingestion, or any other internal dose pathway. With regard to doses arising from aerially dispersed TENORM at the Site, it would not be possible to inhale sufficient dust to cause an acute effect (EPA 2000).

5.2   Acute Exposure Guidelines

The acute exposure guidelines included on each of the data tables (Tables 5-1 to 5-3), used to evaluate the potential for short term health effects, are selected from a variety of lists from scientific and regulatory agencies. A hierarchy of lists is based on a recommendation from EPA Region 9 to use guidelines from the California Environmental Protection Agency (CalEPA) followed by other reputable sources for COPCs without CalEPA guidelines. The following hierarchy would be used for the acute HHRA:

- California EPA's reference exposure levels (RELs), which are available for only five analytes: arsenic, copper, mercury, nickel, and vanadium. Most RELs are based on an exposure time of one hour and define the concentration at which no adverse health effects are expected.

- Emergency response planning guidelines (ERPGs) developed by the American Industrial Hygiene Association. ERPGs are intended to be protective of the general population, and Level II values represent one-hour concentrations at which no irreversible or serious effects are expected to occur that would impair an individual's ability to take protective action.

- Temporary emergency exposure limits (TEELs), from the U.S. Department of Energy, developed for use when no other acute values are available for a given chemical. Level 1 TEELs represent concentrations at which no adverse health effects are expected over a 15-minute exposure time.

5.3   Exposure Concentrations

Three types of short-term exposure concentrations were used 1) measured hourly PM_{10} data, 2) short-term concentrations estimated from 24-hour average concentration data for PM_{10}, TSP and inorganic chemicals, and 3) PM_{10} and inorganic chemicals measured in five dust event samples.

Two adjustments were made to the 24-hour average concentration data resulting in the short-term concentrations as shown on Table 5-1 as EPA-Estimate and Worst-Case Estimate.   The following three steps were used to arrive at the EPA-Estimate:

- ▪ The first step was to determine the 99.7 percent UCL of the data or the maximum concentration, whichever is lower, for each acute COPC;

- ▪ The second step was to adjust the 99.7 percent UCL of 24-hour average concentrations into a concentration representative of one hour. EPA guidance recommends adjusting 24-hour average data to be representative of an hour by dividing by a factor of 0.4 (EPA, 1992; CalEPA 2003).

- ▪ Then the exposure concentrations were matched to the time-frame of the acute short term guidelines for that chemical. For example, the TEEL for aluminum is for a 15 minute interval so the adjusted 24-hour concentration was multiplied by 4.

For the worst-case estimate, the 99.7 percent UCL of the data was assumed to have occurred within the time frame of the acute health-based level. For example, for TSP, the TEEL is based on a 15-minute time frame, and the 99.7 percent UCL of the 24-hour average concentration of TSP was multiplied by 96 (four-15 minute increments per hour for 24 hours). In other words, this estimate assumes that there is no dust in the air for 23 hours and 45 minutes and all the dust occurs in one 15-minute interval. This calculation results in an extremely high estimate of the actual concentration which is a useful screening tool for acute health effects.

The hourly average concentration data for PM_{10} and the dust event data represent shorter periods of time and the only adjustment prior to comparison to the acute health-based guidelines was for the time interval appropriate to that guideline. The exposure concentration for the hourly PM_{10} data was the 99.7 per UCL. The maximum concentration was used for the dust event data because there were only five samples.

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5.4   Acute Risk Characterization

To evaluate the potential for an acute risk, the exposure concentrations of each acute COPCs were compared to the respective health-based acute exposure guideline. Concentrations below the guidelines can be considered safe for short term exposure, and would not likely result in any adverse health effects.

The comparison of estimated maximum short-term concentrations to the health-based acute guidelines is shown for the 24-hour average concentrations (Table 5-1), the hourly PM_{10} concentrations (Table 5-2) and the five samples collected during "dust events" (Table 5-3). None of the estimates of maximum short-term concentrations exceed the respective health-based acute concentrations.

SECTION 6.0

UNCERTAINTY ANALYSIS

This section discusses the level of confidence that can be placed in the findings of the chronic and acute HHRA. There is a level of uncertainty for any risk assessment associated with the various assumptions about exposure and toxicity. The Uncertainty Analysis presents the rationale for whether the risk assessment is representative of the Site and protective of human health. Risk managers take uncertainty into consideration when making decisions on cancer risks within the risk management range (1×10^{-6} to 1×10^{-4}) and hazard values above 1. Sources of uncertainty include the adequacy of the data, the likelihood that the exposure estimates are representative and any actual exposure is not underestimated, and the level of confidence that the toxicity factors represent the health effects.

6.1   Data Adequacy

The chronic and acute HHRAs are based on a substantial amount of verified and validated data – over 500 samples for the majority of chronic COPCs. The data were collected over a period of three years, initially at six locations which were reduced to three locations because of the similarity in the data collected at these stations. The six locations were selected to represent the boundary of the Site to detect any differences, to the extent possible, between upwind and downwind concentrations.

The quality of the collected data met the AQM program objectives. All analytical data were verified and validated in accordance with the Quality Assurance Project Plan (QAPP - Revision 5; Environmental Standards, Inc. and Brown and Caldwell, 2009). The 24-hour average concentration data for particulates, inorganic chemicals and radiochemicals had robust quality control which included the evaluation of field duplicates (i.e., co-located samples), field blanks, filter blanks (i.e., trip blanks), method blanks, blank spikes, and blank spike duplicates. The dust event samples for metals had minimal quality control which included the evaluation of field and filter blanks.

6.2   Exposure Assessment

There is a high level of confidence that exposure is not underestimated in either the chronic or acute HHRAs. For the chronic HHRA, EPA guidance states that the exposure assumptions should create a reasonable maximum exposure (EPA, 1989). The exposure estimates assume that an individual resides at each of the air monitoring stations for 30 years and breathes the outdoor air for 24 hours a day, 350 days a year. This level of exposure is higher than a reasonable maximum level of exposure. In reality, people spend a significant amount of time indoors. The assumption that the concentration in indoor air is 40 percent of outdoor air is used as a conservative estimate in DOE guidance for the estimation of radiochemical risk (DOE, 2001).

For the acute HHRA, one of the exposure evaluations is based on the worst-case assumption that all the particulates (PM_{10} and TSP) measured over a 24-hour period was present in the time period represented by the acute health guideline (i.e., 15-minutes or one hour), and there was no particulates in the air at any other time. The purpose of this unusual assumption was to highlight the fact that the concentrations of PM_{10} and associated metals and inorganic compounds, and TSP do not exceed acute guidelines.

No statistical evaluations relevant to short-term concentrations were possible due to the low number of "dust events" and dust event samples. However, a single comparison of one upwind and one downwind sample of 24-average concentration data measured on June 5, 2007 (a day with the highest recorded wind speeds in the three-year program) showed that arsenic, cadmium, cobalt, copper and some radiochemicals increased in concentration as the air passed over the Site. Regardless of whether this difference is significant or not, the "worst-case" analysis for the acute HHRA (assuming all the particulates from a 24-hour period were released in 15 minutes) indicates that the downwind concentrations are well below acute exposure guidelines. Therefore, if concentration increases result from the Site under certain weather conditions, the increases do not represent a concern to human health.

6.3   Toxicity Assessment

In the chronic HHRA, five metals (copper, iron, molybdenum, silver and zinc) were not included because there are no EPA chronic inhalation toxicity values for these metals. As noted in Section 4.3, EPA guidance is to contact EPA to request inhalation toxicity factors (EPA, 2009a). EPA did not have inhalation toxicity values available for these metals. EPA does not consider any of these metals potential carcinogens.   Potential health effects from these metals are considered noncancer or systemic, and the appropriate toxicity value is an inhalation reference concentration.   EPA suggested converting the oral reference doses for these metals into inhalation reference concentrations (route-to-route extrapolation) rather than exclude these metals from the HHRA. In the past, EPA has used route-to-route extrapolation for some organic chemicals but generally not for metals (EPA, 2004). The toxicological properties of these metals have been well studied. The absence of EPA chronic inhalation toxicity factor likely indicates an absence of long-term systemic health effects via inhalation of environmental levels (as opposed to high occupational levels).   It is also noteworthy that four of these metals (copper, iron, molybdenum and zinc) are required nutrients. Nevertheless, the possibility that these metals may exert some systemic effect is considered in this Uncertainty Analysis.

In considering route-to-route extrapolation it is important to distinguish between effects that occur before a chemical is absorbed into the body (termed "portal of entry effects") and systemic effects that occur elsewhere in the body after a chemical is absorbed. For example, irritation of the gastrointestinal tract by ingested copper may not be a relevant effect of concern for inhaled copper. However, oral toxicity information may not be predictive of portal of entry effects in the lungs from inhaled chemicals. It is also necessary to consider if absorption, distribution, and metabolism of a chemical differ depending on whether the chemical is ingested or inhaled. Once an airborne particulate is inhaled, the particle may become lodged in the lungs or it may be expelled from the trachea and swallowed. Thus, a fraction of an inhaled dose of a chemical may subsequently be ingested. Chemicals in or on particles lodged in the lungs may either remain in the lungs or may cross over into the bloodstream and enter the systemic circulation. These factors need to be considered in determining the relevance of oral toxicity data to assessing effects of inhaled chemicals.

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As part of this Uncertainty Analysis, a two-phased approach was used to assess potential risk for chronic exposures to copper, iron, molybdenum, silver and zinc. First, the potential for direct effects on the lungs (i.e., portal of entry effects) was qualitatively assessed by a review of studies of occupational exposures and, where applicable, by comparison of the occupational exposures with upper-bound estimates of concentrations at the site boundary. Second, potential for noncancer (systemic) effects was assessed by calculating HQ values for these metals using route-to-route extrapolation. The oral reference dose was multiplied by 70 kg for an adult and divided by 20 m^3 of air daily to convert it into an inhalation reference concentration (EPA, 1997). The potential for chronic systemic effects was further assessed by calculating an upper-bound estimate of a dose that could be absorbed if the entire inhaled dose was absorbed systemically, and comparing that dose to recommended dietary allowances and dietary intakes. The following is a discussion of each of the metals, valuation of potential portal of entry effects, the results of the HQ calculation, and comparison of the dose to recommended daily allowance for required nutrients or dietary intake for silver.

The exposure point concentrations are presented in Appendix A and the HQ calculations followed the same protocols as used for other noncancer health effects in Section 4.

6.3.1 Copper

Evaluation of Potential Portal of Entry Effects - Studies on inhalation health effects of copper are largely based on occupational exposure to high levels of copper dust or copper salt aerosols (ATDSR, 2004). The occupational concentrations were hundreds or thousands time higher than those found in the dust in the air at the Site. Copper is listed as a respiratory irritant via inhalation at these levels. The reported health effects include nausea and gastrointestinal upset as well as irritation of the lungs and eyes, and effects of the blood and liver (ATSDR, 2004).

Evaluation of Potential Systemic Effects - The oral reference dose of 0.04 mg/kg/day was derived from the drinking water standard for copper of 1.3 milligrams per liter (mg/L) and is based on nausea and gastrointestinal upset (NAS 2000). Although this endpoint is not likely applicable to inhalation exposures, route-to-route extrapolation was used to calculate an

inhalation reference concentration. The highest chronic exposure concentration of copper is 0.0000278 mg/m^3 reported at AM-3 and the associated HQ value is 0.0002. The HQ indicates no potential for adverse effects if the entire inhaled dose was absorbed into the body. The estimated daily dose from copper is 0.0000076 milligrams per kilogram of body weight per day (mg/kg/day) which corresponds to a dose of 0.0001 mg/day for a 15 kg child and 0.0005 mg/day for a 70 kg adult.

Copper is an essential nutrient and is found in most animal and plant tissues (OSU, 2010). It is a component of many enzymes and is essential for the utilization of iron. The recommended daily allowance ranges from 0.2 mg/day for infants to 1.3 mg/day for a breast-feeding mother (OSU, 2010). The highest inhaled dose of copper from re-suspended soil at the Yerington site boundary is less than 1/1000th of the recommended daily dose of copper. Foods that are good sources of copper include legumes, nuts cereals and chocolate. For example, two tablespoons of peanut butter contain 0.185 mg of copper (OSU, 2010).

6.3.2 Iron

Evaluation of Potential Portal of Entry Effects - There is a condition called siderosis which is fibrosis of the lungs caused by inhalation of iron dust that can occur among welders and other metal workers (http://www.websters-online-dictionary.org/si/siderosis.html). The levels of iron for welders and metal workers are hundreds or even thousands time higher than found in dust at the Site.

Evaluation of Potential Systemic Effects - The oral reference dose for iron of 0.7 mg/kg/day is based on gastrointestinal health effects (EPA, 2005). Although this endpoint is not likely applicable to inhalation exposures, route-to-route extrapolation was used to calculate an inhalation reference concentration. The highest chronic exposure concentration of iron is reported 0.0004 mg/m^3 at AM-4 and the associated HQ value is 0.0002. The HQ indicates no potential for adverse effects if the entire inhaled dose was absorbed into the body. The estimated

daily dose from iron is 0.0001 milligrams per kilogram of body weight per day (mg/kg/day) which corresponds to a dose of 0.0016 mg/day for a 15 kg child and 0.008 mg/day for a 70 kg adult.

Iron is a required nutrient and an essential ingredient in hundreds of proteins and enzymes (OSU, 2010). Iron deficiency is the most common nutrient deficiency in the U.S. (OSU, 2010). The recommended daily allowance ranges from 0.27 mg/day for infants up to 27 mg/day for a pregnant woman (OSU, 2010).

6.3.3   Molybdenum

Evaluation of Potential Portal of Entry Effects - No studies on the inhalation of molybdenum were located in the EPA IRIS file and there is no ATSDR toxicological profile for this metal.

Evaluation of Potential Systemic Effects - The oral reference dose for molybdenum of 0.005 mg/kg/day is based on increases in uric acid concentrations in the blood associated with gout (EPA, 2010). Although this endpoint is not likely applicable to inhalation exposures, route-to-route extrapolation was used to calculate an inhalation reference concentration. The HQ indicates no potential for adverse effects if the entire inhaled dose was absorbed into the body. The highest chronic exposure concentration of molybdenum is 0.0000008 mg/m^3 reported at AM-4 and the associated HQ value is 0.00005. The exposure concentration is based on the maximum concentration found in any sample. The estimated daily dose from molybdenum is 0.0000002 milligrams per kilogram of body weight per day (mg/kg/day) which corresponds to a dose of 0.000003 mg/day for a 15 kg child and 0.00002 mg/day for a 70 kg adult.

In people, molybdenum is known to function as a cofactor for three enzymes (OSU, 2010). The daily recommended doses of molybdenum for good health range from 0.002 mg for infants to 0.05 for pregnant woman (OSU, 2010). High doses of molybdenum can interfere with uptake of copper and cause copper deficiency (OSU, 2010). Otherwise, the Food and Nutrition Board (FNB) of the Institute of Medicine found little evidence that molybdenum excess was associated with adverse health outcomes in generally healthy people (OSU, 2010).

6.3.4   Silver

Evaluation of Potential Portal of Entry Effects - The ATSDR profile for silver states that no studies showing systemic effects after inhalation of silver were located. Silver has been shown to be a respiratory irritant in silver metal workers (ATSDR, 1990). No silver concentrations in the air were reported; however, it is reasonable to conclude that silver metals workers are exposed to higher levels of silver than are found in the dust at the Site.

Evaluation of Potential Systemic Effects - EPA based the oral reference dose of 0.005 mg/kg/day on a condition called "argyria" which is a medically benign but permanent bluish-gray discoloration of the skin (EPA 2010; ATSDR 2004). Argyria results from the deposition of silver in the dermis and also from silver-induced production of melanin. The highest chronic exposure concentration of silver was 0.00000001 mg/m^3 reported at AM-1 and the associated HQ value is 0.0000007. The estimated daily dose from silver is 0.000000004 milligrams per kilogram of body weight per day (mg/kg/day) which corresponds to a dose of 0.00000005 mg/day for a 15 kg child and 0.0000002 mg/day for a 70 kg adult.

People ingest small amounts of silver from dietary sources. The oral intake of silver from a typical diet has been estimated to range from 0.027-0.088 mg/day (EPA, 2010). The lowest dietary intake is more than 100,000 times higher than the highest estimated dose of silver from dust in air at the Site. Silver compounds have been employed for medical uses for centuries. In the nineteenth and early twentieth centuries, silver was used in the treatment of syphilis; more recently it has been used as an astringent in topical preparations (EPA, 2010).

6.3.5   Zinc

Evaluation of Potential Portal of Entry Effects –There are studies on the inhalation effects of zinc in occupational settings where the concentrations of zinc in the air were 5 or more orders of magnitude greater than found in air at the Site (ATSDR, 2005). The health effects noted were for the respiratory system and nausea.

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Evaluation of Potential Systemic Effects - The oral reference dose for zinc of 0.3 mg/kg/day is based on an antagonistic interaction with copper which reduces the amount of copper in the body. The highest chronic exposure concentration of zinc was 0.000007 mg/m^3 reported at AM-4 and the associated HQ value is 0.000006. The estimated daily dose from zinc is 0.000002 milligrams per kilogram of body weight per day (mg/kg/day) which corresponds to a dose of 0.00003 mg/day for a 15 kg child and 0.0001 mg/day for a 70 kg adult.

The Linus Pauling Institute notes that "Numerous aspects of cellular metabolism are zinc-dependent. Zinc plays important roles in growth and development, the immune response, neurological function, and reproduction." (OSU, 2010). The recommended daily allowance of zinc ranges from 2 mg a day for infants to 13 mg a day for young breast-feeding mothers (OSU 2010). The recommended daily allowance is more than 1,000 times higher than the estimated doses from dust in air at the Site.

6.3.6   Summary of Findings for Toxicity Factors

The following observations can be made on the potential health effects for copper, iron, molybdenum, silver and zinc via inhalation of dust at the Site:

- Inclusion of these HQ values in the total risk (including background) would not cause the cumulative HI value for any station to exceed 1, the acceptable level for non-cancer health effects.

- Any potential doses for the required nutrients (copper, iron, molybdenum and zinc) are well below the recommended daily levels.

- The potential dose from silver is below daily sources in the diet and is not associated with a dose that caused adverse health effects via oral exposure.

- Copper, iron and zinc are known to affect the respiratory system, largely as irritants, but only at concentrations that are orders of magnitude above those found in re-suspended soil in the air at the Site.

SECTION 7.0

CONCLUSIONS

The purpose of the chronic and acute HHRAs was to determine if any Site-related increases in concentrations of dust and associated chemicals and radiochemicals pose a potential concern to human health. The results do not indicate a potential for increased health effects associated with particulates from the Site. In addition, the results of the chronic and acute HHRAs show that inhalation of PM_{10}, regardless of the source (background or site-related), is not likely to result in adverse health conditions.

In the chronic HHRA, the cumulative cancer risks and noncancer hazard values (including background) are within the risk management levels set by EPA. In the acute HHRA, none of the estimates of short-term exposure (including a "worst-case" estimate) exceeded acute guidelines.

The comparison of the upwind and downwind 24-hour average concentrations indicates that some parameters such as PM_{10}, aluminum and copper have higher concentrations in the downwind samples. However, the health risks are well below EPA's threshold for noncancer health effects. Even if releases from the Site cause an increase above background, the total concentration is still below the acceptable limit.

For the acute HHRA, it was noted comparison of one set of 24-hour average samples collected during the day of the highest wind and dust conditions recorded during the three-year air quality program (June 5, 2007) shows that concentrations of some parameters may increase as wind passes over the Site under these conditions. However, the analysis of the short-term data indicates that any such increases will remain below health-based guidelines.

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